Clean Air Research Program
Source to Health Outcomes/Multi-pollutant
Summary and Abstracts

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Session 3: Source-to-Health Outcomes/Multi-pollutant

1.0 Introduction

Air pollution by its very nature comprises a complex mixture of many compounds from primary emission sources and via secondary transformation reactions in the atmosphere. As a result, real-world exposures to air pollution are a complex mixture of both gases and particles. In dealing with a challenging problem, scientists and engineers often reduce the problem into simpler forms to gain insights and inform strategies aimed at better managing the problem. The Clean Air Research program has recently had a strong emphasis on particulate matter (PM) and ozone (O3) because these two air pollutants are important risk drivers for human mortality and morbidity. This approach has allowed us to better understand the important processes, linkages and mechanisms across the source-to-health risk paradigm on a pollutant-by-pollutant basis for the six "criteria" pollutants and laid the scientific foundation for the National Ambient Air Quality Standards (NAAQS) for those pollutants as reflected in the Integrated Science Assessments for each one: PM, O3. sulfur oxides (SOX), nitrogen oxides (NOX), carbon monoxide (CO), and lead (Pb). While specific health outcomes have been attributed to single pollutant exposures from these pollutants (e.g. mortality and $PM_{2.5}$), and recent research has also suggested that ozone is also associated with human mortality, it is becoming increasingly clear that the interactions of pollutants may be an important determinant of risk to human and ecological health.

When the NAAQS were first established starting in 1971, the standards were written and the pollutants considered on an individual basis consistent with our thinking at the time. Science has progressed considerably since then and now we recognize that many of the six criteria and other pollutants interact in the atmosphere in a variety of ways. For example, it has been long understood that NO_2 is directly involved in the secondary formation of O_3 through atmospheric photochemical reactions with volatile organic compounds (VOCs). One terminal product of NO_2 photochemistry involves formation of nitrate (NO^{3-}), often a substantial component of $PM_{2.5}$, especially in the western U.S. Additionally, SO_2 emissions are oxidized in the atmosphere forming sulfate (SO_4^{2-}), another substantial component of $PM_{2.5}$, particularly in the eastern U.S. Although VOCs are not criteria pollutants, they undergo atmospheric photochemical reactions to produce secondary organic aerosols as well, yet another substantial component of $PM_{2.5}$ in most airsheds. In some airsheds, selected VOCs are controlled to help reduce ozone formation; other VOCs are regulated under the Hazardous Air Pollutants (HAPs) Program, established under the 1990 Clean Air Act Amendments. The HAPs regulations are aimed at source sectors and can regulate single or multiple pollutant emissions from these sources. However, the criteria pollutants and HAPs are regulated independently and cannot be combined under EPA's current legislative authority.

The current Multiyear Plan (MYP) for the Clean Air Research program reflects a major shift in focus by combining several program areas that previously targeted air pollutants like PM, O3, and HAPs individually. Although it is essential to provide support for the individual NAAQS pollutants that continue to be regulated individually, a multi-pollutant research program better reflects real-world air pollution problems and parallels the evolving scientific and regulatory context of urban, regional, and global air pollution. To a large degree, this is a natural progression in scope, especially with respect to PM, which itself is a mixture that differs in size, composition, and production in the atmosphere. Furthermore, these physical and chemical features often vary in time and space depending on the nature of the sources contributing to primary emissions and on the meteorology affecting secondary pollutant transformations. A well-known example is the interaction between emitted PM, NO_x, and SO_x and their transformations in the atmosphere that can result in deposition of nitrate and sulfate particles which can have deleterious ecological effects. EPA has recognized the important interrelated emissions, production, and biological effects due to nitrogen and sulfur deposition in the environment and is now preparing the first joint NAAQS review for SO_x and NO_x specifically for a standard to protect ecological health. Ecological health standards are referred to in the NAAQS language as "secondary standards" with "primary standards" being devoted to human health effects. Similarly, as human health effects are increasingly attributed to air pollutant mixtures and the interaction of pollutants in the atmosphere and in biological systems, this research can inform additional multi-pollutant standards.

Critical components from the single-pollutant research approach are used to develop an understanding of how emitted source pollutants affect ambient concentrations, how these concentrations relate to exposures, and, in turn, how exposures relate to health outcomes. This information provides the fundamental linkages for evaluating health impacts, ascertaining the origins (both direct source emissions and atmospheric transformations) of air pollutants which are most egregious in terms of health risk, and in developing effective mitigation strategies for multiple air pollutants co-occurring in the atmosphere.

The research described in this overview primarily supports Long Term Goal 2 of the Clean Air Research MYP by providing methods, measurements, and models to identify the origins of air pollutants that substantially contribute to health risks. These scientific tools provide key insights into source emissions, atmospheric processes and concentrations, and human exposures and health effects as well as the relationships among these elements of the source to outcome paradigm. As outlined in the Clean Air Research MYP, the key science questions being addressed by Source-to-Health Outcome/Multi-pollutant research are:

- How can we assess and manage risks from real-world exposures involving complex mixtures of air pollutants that fall into many physical-chemical classes?

- What role does the interaction of multi-pollutant atmospheres and its individual constituents have on public health impacts due to air pollution?

Because the research described in this overview represents a recent shift in focus it largely contributes to the completion of future Annual Performance Goals (APG) in the MYP (2010 and beyond). The products of this research, however, are already being used by ORD's primary clients in the Office of Air and Radiation to inform, develop, and evaluate multi-pollutant air quality management strategies at the federal, state, and local levels in the context of national air quality regulations.

2.0 Research Drivers

Over the past five years various scientific advisory panels have emphasized the importance of developing an integrated, multi-pollutant approach to air quality research and management. These panels support the introduction of a multi-pollutant perspective into all aspects of air quality management: measurement, prevention, and mitigation of its adverse effects on human and ecosystem health.

In its fourth report issued in 2004, the National Research Council's (NRC) Committee on Research Priorities for Airborne Particulate Matter indicated the need for EPA to shift focus from a single pollutant (PM) to a multi-pollutant approach. The PM program had made considerable progress and the committee felt it was time for EPA to consider all components of the atmosphere including PM, other criteria pollutants and HAPs and their collective impact on human and ecological health. The report indicated that research that considers the mixture of air pollutants will provide a more complete understanding of how realistic multi-pollutant atmospheres and exposures lead to adverse health effects. A multi-pollutant research strategy may also uncover previously unknown synergisms "among the mixture of components that give the mixture greater risk than would be anticipated from the risks estimated from individual components". While there are many challenges, the Committee indicated the high likelihood that the information resulting from a multi-pollutant science-based approach "should have clear benefit in optimizing both the cost-effectiveness and the health benefits of future air quality management strategies".

The NRC Committee on Air Quality Management recommended a transition toward an integrated, multi-pollutant approach that targets the most significant exposures and risks. The Committee's report, *Air Quality Management in the United States*, identified limitations in the current air quality management system and provided a set of overarching long-term objectives and recommendations to guide future improvement of the air quality management (AQM) system. The Committee endorsed a multi-pollutant approach partly because such an approach "should minimize the possibility that control strategies implemented for one pollutant will inadvertently increase the concentrations of another pollutant…" The Committee recognized there are severe limitations of evaluating and setting the NAAQS one pollutant at a time because many air pollutants and their precursors share common sources. The Committee also emphasized the importance of assessing the effectiveness of the AQM (i.e. accountability) in reducing emissions, ambient concentrations, exposures and effects. While considerable progress has been made in reducing emissions and ambient concentrations, it is not clear how effective these reductions have translated into benefits to human health and welfare.

The transition towards multi-pollutant research in ORD's Clean Air Research program reflects the needs of our clients and stakeholders at the state and local levels to improve overall air quality in a multi-pollutant context. EPA began the transition to a multi-pollutant approach following the recommendations above and similar ones made by the Clean Air Act Advisory Committee (CAAAC) and the Clean Air Scientific Advisory Committee (CASAC). The Office of Air Quality Planning and Standards (OAQPS), a key client of the ORD Clean Air Research program, reorganized away from pollutant-specific groupings to a more sector-based structure to improve HAPs control and multi-pollutant air quality assessment. In 2005, OAQPS and the State of Michigan initiated a pilot air quality management program for the Detroit metropolitan area with the intent of developing and evaluating a first ever multi-pollutant State Implementation Plan (SIP). Currently ORD is working with OAQPS on a multi-pollutant risk reduction strategy in support of the Detroit multi-pollutant SIP (see the poster presented by Jenkins). Also, ORD and OAR held a workshop in March 2008 to discuss multi-pollutant research and program needs and another workshop is scheduled for September 2009. With future air quality policy moving in this direction, research is needed across the source-to-health outcome paradigm to support and inform a comprehensive multi-pollutant air quality management program.

Considerable scientific progress has been made over the years in understanding the role of specific air pollutants on public health. As a result, the state of scientific understanding has evolved to a point where a multi-pollutant research approach is now needed to better inform *and* better evaluate comprehensive air quality management, completing the management circuit with this accountability research. Compliance with air quality regulations is often difficult but the benefits have been very valuable (see OMB 2008 Report on Benefits of Clean Air Regulations/Abatement). Optimizing these benefits requires an iterative feedback between evaluating the effects of regulations and identifying additional mitigation strategies that may be needed. This feedback is important because it can be used to identify additional measures that can be taken to achieve the intended benefits of an air quality management program. Valuing the benefits of these efforts demonstrates the role these actions play in improving AQ and public health. If benefits cannot be demonstrated, then additional measures are needed.

3.0 Research Summary

The Clean Air Research program has already begun the transition to a multi-pollutant paradigm. The current MYP combined and integrated three MYPs and research strategies (PM, O_3, and HAPs) into a single plan to better coordinate and leverage research across these themes. Earlier MYPs for PM, O3 and HAPs approached each program area separately with little cross-theme coordination and integration and separate tracking and budgeting operations. As already noted, the science and regulatory programs are evolving toward a multi-pollutant perspective that better reflects the realities of human exposures and offers the potential for more effective control and public health protection.

The following sections provide a brief description of the Clean Air Research Program's Source-to-Health Outcome/Multi-pollutant research efforts and describe the posters summarizing the research. These research efforts are already providing important insights into the complexities of multi-pollutant sources and atmospheres and their relationship with human health effects. Also, the research is contributing to the APGs outlined in the Clean Air Research MYP.

3.1 Linking Multi-pollutant Sources and Health Effects

The Clean Air Research MYP emphasizes a source-to-outcome approach that is intended to provide insights along the risk paradigm in a multi-pollutant context. The MYP was developed in consultation with OAR. Together, we identified near-road exposures as an issue that merited considerable attention and resources. Evaluating near-road air pollution requires an integrated, multidisciplinary field and laboratory research approach allowing for the assessment of mitigation strategies. The near-road research is a noteworthy example of an integrated, multidisciplinary research program that spans across ORD and involves extramural researchers. **The poster presented by Baldauf** (Poster 2-01) summarizes research studies aimed at characterizing air quality and exposure impacts from traffic emissions in the near-road environment. These studies examined the spatial and temporal variability of a number of air pollutants emitted by motor vehicles and their near-road dispersion patterns. The research also examined how PM composition likely changes as it is transported indoors in residences located near major roads. The effect of roadway configuration and roadside structures (noise barriers and vegetation) were found to have a considerable influence on dispersion patterns of motor vehicle related air pollutants. These data are being used to develop improved algorithms for dispersion models to better estimate the distribution of air pollutants in near-road applications. This information will be useful for OAR's Office of Transportation and Air Quality (OTAQ) in their mobile source program.

A growing number of health studies have identified adverse health effects, including respiratory and cardiovascular disease, cancer, birth outcomes and defects, and even mortality, for populations living near major roads. These initial reports are raising concerns about the building of schools near roadways, the quality of indoor air in existing schools near roadways, and the general health impacts on people living near roads. In a recently released report, the Health Effects Institute assembled a panel to critically review the body of available scientific literature on traffic related exposures and health effects. The report concluded that additional work was needed to address the impact of traffic on childhood respiratory disease and cancer, and cardiovascular disease and cancer in adults. **The poster presented by Neas** (Poster 2-02) highlights research results from several studies that examined the relationship between traffic exposure and a variety of health outcomes. The results indicate associations between traffic and cardiac function and disease, respiratory disease, birth weight, systemic inflammation and lung cancer. This research provides evidence for the link between motor vehicles and human health outcomes. Findings from the extramurally funded near-road research in conjunction with other studies were influential in developing a new California state law prohibiting the construction of new schools within 500 feet of freeways. Future research in this area involves a coordinated study of near-road exposures and health effects. This multidisciplinary study is a cooperative agreement between the University of Michigan and ORD researchers.

The impact of stationary sources on air quality, exposures and health effects is also an active area of research in the Clean Air Research MYP. Stationary sources include power plants and industrial sources that have long been recognized for contributing to poor air quality and have been the focus for emissions reductions to meet the NAAQS. The research involves the application of tools (methods, measurements and models) developed and refined in other areas of the Clean Air Research program (see the Air Quality overview and posters for more details). **The poster presented by Burke** (Poster 2-03) describes the use of high-time resolution measurement techniques in conjunction with modeling analyses to determine the impact of local and regional sources of air pollution on air quality and human exposures. These studies have been performed in several locations with varying source complexity including power plants, industrial facilities and airports. The poster also describes an apportionment technique in CMAQ used to track the composition and sources of carbonaceous aerosols across spatial scales ranging from urban to regional to national. OAQPS relies heavily on the CMAQ model for both the NAAQS and HAPs programs, as well as the National Air Toxics Assessment (NATA) database. **The poster presented by Madden** (Poster 2-04) highlights three approaches used to assess the relationship between specific stationary sources of air pollution and health effects. The approaches include toxicity (in vivo and in vitro) studies involving healthy and sensitive animal models and human populations. Mortality and morbidity in human populations were examined in specific geographic areas with various source contributions. Finally, national health effects databases have been examined to relate mortality and other health effects with areas of the U.S. with pronounced sources. Results of these analyses indicate the importance of the relative composition of air pollutants, especially on cardiopulmonary toxicity, while distinct regional differences have been found for coarse PM. Findings from these studies provide critical support to inform the PM NAAQS review.

Table 1 identifies the Annual Performance Goals (APG) in LTG 2 of the MYP to which the *Linking Multi-pollutant Sources and Health Effects* research described above contributes.

Table 1. Contributions of Research on *Linking Multi-pollutant Sources and Health Effects* to the Clean Air Research MYP

APG #	APG Description	Date	Contributions through 2009
APG 17	Develop methods and enhance tools to link health and ecosystem impacts to air pollution sources, including remote sensing and data combination techniques	2010	Estimate source contributions in a study of human exposures to multiple pollutants in Detroit
APG 18	Determine the significance of near-road emissions/exposures and related health risks from mobile sources and evaluate risk management options	2012	Characterize composition and variability of air pollutants near-roads
			Assess the influence of noise barriers and vegetation on near-road air quality
			Characterize relationships between traffic/near-road exposures and various health effects
APG 20	Investigate relationships between sources, exposures, and health effects using a variety of approaches that focus on single geographic locations or specific sources (other than roadway) and identify options to reduce exposures for sources of concern	2012	Integrated application of source apportionment techniques and health effects from multi-pollutant stationary sources

3.2 Atmospheric Transport and Transformation

Air pollutants originate from direct emissions from a multitude of sources as well as through atmospheric transformations of emission precursors. Consequently, air masses typically contain many pollutants present in differing amounts depending on the types of sources impacting an area as well as atmospheric conditions that have the potential for transforming emissions precursors. **The poster presented by Kleeman** (Poster 2-05) examines how atmospheric chemical reactions and processes alter the composition of air pollutants and their potential impact on health effects. The poster illustrates the importance of gas-particle phase partitioning of semi-volatile organic compounds. The volatilization of primary organic aerosols (POA) has implications on the production and aging of secondary organic aerosols (SOA) and source apportionment analyses using molecular markers. Atmospheric aging may also have an impact on health effects, although results were mixed: concentrated ambient particles (CAPs) studies suggested that aged primary particles induced greater inflammation than fresh particles while an epidemiology study showed mortality effects associated with ozone and sulfate was significant in some cities and not in others. As understanding improves, this type of research can enhance the CMAQ model as well as contribute to the science informing multiple NAAQS reviews and the HAPs program.

Multi-pollutant atmospheres can also be generated under controlled conditions and used to study the important transformations that occur in the atmosphere as well as health outcomes. **The poster presented by Koutrakis** (Poster 2-06) describes the use of simulated multi-pollutant atmospheres in toxicological studies. Primary emissions from diesel and coal combustion sources were atmospherically aged in photochemical chambers. These innovative studies revealed significant pulmonary and cardiac oxidative stress were produced by aging emissions from coal plants, and that the biological potency of diesel emissions was affected by changes in composition due to aging. Atmospheres simulated from the aging of synthetic gas and PM mixtures generated carbonyls (partially oxygenated hydrocarbons), significant contributors to cell death and inflammation. Understanding how source emissions interact and undergo transformations in the atmosphere is important for OAR when regulating both stationary and mobile sources, as well as developing new fuels standards.

Sources emit a multitude of air pollutants whose relative amounts may be used to apportion the contributions of source emissions impacting air quality and linking with health effects. **The poster presented by Duvall** (Poster 2-07) describes the application of source-receptor models to identify emission sources in several U.S. cities that are associated with specific health outcomes. The poster highlights results from a number of interdisciplinary studies involving atmospheric science, exposure and health effects researchers that relate mobile sources to markers for lung inflammation and emergency department cardiovascular related visits. Secondary sulfate was associated with emergency department respiratory related visits and cardiovascular mortality. Source-receptor models use multi-pollutant datasets, primarily PM components to this point, to relate observed air pollutant data with source impacts. These models will be used in future studies to examine additional gas and particle phase source marker compounds to reduce the uncertainty in identifying sources and their potential impact on health effects. This information is critically important to describe the degree to which sources of multi-pollutant atmospheres impact public health.

Table 2 identifies the Annual Performance Goals (APG) in LTG 1 of the MYP to which the *Atmospheric Transport and Transformation* research described above contributes.

Table 2. Contributions of Research on *Atmospheric Transport and Transformation* to the Clean Air Research MYP

APG #	APG Description	Date	Contribution
APG 18	Determine the significance of near-road emissions/exposures and related health risks from mobile sources and evaluate risk management options	2012	Characterizing effects from simulated multi-pollutant atmospheres of diesel emissions
APG 19	Conduct multi-pollutant, multicity studies to evaluate the relative associations of PM, components/sources of the mixture, and gaseous co-pollutants, with key human health events in multiple U.S. cities	2012	Source-receptor analyses and relationships with health effects in multiple U.S. cities
APG 20	Investigate relationships between sources, exposures, and health effects using a variety of approaches that focus on single geographic locations or specific sources (other than roadway) and identify options to reduce exposures for sources of concern	2012	Characterizing effects from simulated multi-pollutant atmospheres generated by specific source emissions
			Source-receptor analyses and relationships with health effects in single locations

3.3 Influence of Airshed on Multi-pollutant Air Quality and Health Effects

Regional differences in effects have been found for various air pollutants. Elucidating the factors that lead to these regionally heterogeneous effects is an important issue for OAR to consider when setting national standards such as the NAAQS. There are a number of factors that may contribute to these differences including social and demographic factors, and the mixture of sources contributing to air pollution in an airshed affects multi-pollutant exposures. **The poster presented by Dominici** (Poster 2-08) describes several studies that examine geographic heterogeneity in health effects across the U.S. and Europe as well as the role of PM components. Results indicate that the short-term effects of PM on mortality and morbidity vary by geographical regions. A multi-site time series study found strong regional differences between cardiovascular related hospital admissions and daily $PM_{2.5}$ levels in Medicare enrollees. There are a number of factors that may explain this geographical variability including weather, socio-economic variables, and the chemical composition of PM. Indeed, significantly higher cardiovascular admissions were associated with elemental carbon (a marker for traffic), and vanadium and nickel (markers for oil combustion). Studies like these yield important insights into the role of PM components that derive from various sources.

The composition of multi-pollutant atmospheres and exposures likely varies according to geographic region and the relative contributions of both local and regional sources. **The poster presented by Norris** (Poster 2-09) describes an integrated research approach to evaluate the impact of multiple local and regional sources on air quality, exposures and effects in an urban airshed. A combination of sampling and analytical methods development, model development and application of these tools in targeted studies provides insight into the various sources impacting an airshed. Studies have been performed in a number of U.S. locations, primarily in the Midwest and Southeast U.S. Toxicology studies are performed concurrently to better understand the relationship between sources and effects. These studies also provide useful information to aid state and local air pollution control strategies to reduce the impact of source emissions on air quality.

The NAAQS and other regulatory programs focus on reducing emissions to improve ambient air quality, thereby reducing human exposures and health effects. Research is needed to develop indicators across the source-to-health outcome paradigm that can be used to evaluate the effectiveness of regulatory programs intended to reduce impacts on public and environmental health. **The poster presented by Garcia** (Poster 2-10) describes approaches and studies aimed at developing process level indicators for ambient concentrations, exposures and health effects to assess the effectiveness of emissions control strategies. These control strategies arise from regional reduction programs (e.g. NO_x SIP call), mobile source emissions reductions during the Olympics in Atlanta and Beijing, and nation-wide reductions in ambient concentrations achieved through the NAAQS. The studies described in the poster are a coordinated effort involving both intramural research conducted by EPA and extramural research supported by HEI. A recent paper, already widely heralded, found increased life expectancy was associated with reductions in $PM_{2.5}$ concentrations across the U.S. Developing and evaluating indicators across the risk paradigm will be needed to determine if regulatory programs to reduce multi-pollutant emissions also result in positive impacts on public health.

Table 3 identifies the Annual Performance Goals (APG) in LTG 2 of the MYP to which the *Influence of Airshed on Multi-pollutant Air Quality and Health Effects* research described above contributes.

Table 3. Contributions of Research on *Influence of Airshed on Multi-pollutant Air Quality and Health Effects* to the Clean Air Research MYP

APG #	APG Description	Date	Contribution
APG 15	Develop a framework to assess the effectiveness of air pollution regulations and control strategies in reducing human exposure, ecosystem deposition, environmental and health impacts	2009	Studies to evaluate the effect of local and regional air pollution control strategies on air quality, exposures and health effects
APG 19	Conduct multi-pollutant, multicity studies to evaluate the relative associations of PM, components/sources of the mixture, and gaseous co-pollutants, with key human health events in multiple U.S. cities	2012	Multicity time-series study of PM and components with cardiovascular effects
APG 20	Investigate relationships between sources, exposures, and health effects using a variety of approaches that focus on single geographic locations or specific sources (other than roadway) and identify options to reduce exposures for sources of concern	2012	Application of a suite of receptor measurement and modeling analyses in several U.S. cities to identify local and regional source contributions
APG 22	Refine the Air Accountability Framework through the use of pilot or test-bed activities or related environmental opportunities for proof of concept	2012	Studies to evaluate the effect of local and regional air pollution control strategies on air quality, exposures and health effects

3.4 Assessing and Managing Multi-pollutant Exposures and Health Effects

Constituents in a multi-pollutant mixture may interact in ways that alter the toxicity of the mixture and possibly increase the risks due to multi-pollutant exposures. This is an important consideration in developing air quality regulations that reflect real-world conditions. **The poster presented by Pinkerton** (Poster 2-11) examines the interactions of multiple pollutants in eliciting health effects. The research found sulfate particles, and not $PM_{2.5}$ mass, increase mortality effects associated with ozone suggesting an enhanced effect for aged air masses. Synergistic effects in cardiac function were found with ozone and long-term exposure to lead. Toxicology studies in animals and humans suggest synergistic effects for particle composition including soot, metals as well as distance from roadways. These interactions are important to understand when developing NAAQS in a multi-pollutant context.

The indoor environment, where people spend a large amount of time, may result in significant interactions between the mixture of ambient pollutants that infiltrate indoors and indoor air pollutants. These complexities are important to understand because indoor air pollutants may alter the nature and severity of health effects from multi-pollutant exposures. **The poster presented by Williams** (Poster 2-12) describes field and controlled laboratory studies to evaluate multi-pollutant impacts on residential and human exposures. These studies have determined the impact of ambient-based pollution sources on the residential microenvironment and human exposures. Integrated personal exposure and residential microenvironmental studies provided data on simultaneous exposures to multi-pollutant classes including PM components, criteria gases and VOCs. Test house and chamber research revealed the production of several air pollutants (e.g. PM, carbonyls) indoors in the presence of ambient gases (O_3 and NO_2) and air fresheners.

Multi-pollutant atmospheres originate from source emissions and atmospheric processing, which may alter the composition and toxicity of the mixture. **The poster presented by Wexler** (Poster 2-13) describes research to investigate the differential toxicity of sources on health effects. Epidemiological studies found mortality risks from stroke and diabetes were more strongly associated with exposures to traffic than power plants. Heart rate variability was significantly associated with BC, a marker for local traffic, and sulfate, a marker for regional air pollution from power plants. These results, along with results from future studies, are important because they demonstrate the need to consider the origins of multi-pollutant atmospheres in eliciting health effects.

Reducing the effects of multiple pollutants on humans and the environment begins with effective control strategies. Control technologies need to be designed and evaluated to reduce multi-pollutant emissions at their source. As such, control strategies should be designed in consideration of their ability to reduce emissions of multiple pollutants. **The poster presented by Hutson** (Poster 2-14) describes research to investigate multi-pollutant control technologies for emissions sources. Wet scrubbers designed to remove SO_2 and NO_x have been amended to remove other pollutants, such as oxidized forms of Hg. Additionally, a modeling framework has been developed that considers multi-pollutant control strategies for criteria pollutants and HAPs. The framework has been used to evaluate cap-and-trade programs for the cement sector with expansion expected to other emissions sectors.

Table 4. Contributions of Research on *Assessing and Managing Multi-pollutant Exposures and Health Effects* to the Clean Air Research MYP			
APG #	**APG Description**	**Date**	**Contribution**
APG 20	Investigate relationships between sources, exposures, and health effects using a variety of approaches that focus on single geographic locations or specific sources (other than roadway) and identify options to reduce exposures for sources of concern	2012	Multi-pollutant exposure studies in several U.S. cities with varying source complexity
			Health effects studies to evaluate the relative toxicity of different sources
APG 21	Evaluate whether control technologies deployed for major stationary and mobile sources are achieving the pollutant reductions anticipated and whether these technologies are having any unintended health and environmental consequences	2012	Evaluation of multi-pollutant control technologies for emissions reductions and application of a modeling framework to evaluate sector based multi-pollutant emissions

4.0 Impacts and Outcomes

The source-to-health outcome approach has been a central component of the Clean Air Research program over the past several years. This approach was initially applied to single pollutants to provide relevant information that primarily supported the scientific basis of the NAAQS. PM and O3 were the primary focus of the Clean Air Research program on source-to-health outcome because they are the principal risk drivers among air pollutants affecting human health and were identified as such by our stakeholders in OAR. This single pollutant focus has also been useful in probing the complexities of the science and allowed it to evolve to more accurately reflect the more realistic multi-pollutant atmosphere. Not surprisingly, the results of recent research points to the need to consider other pollutants in combination with PM and O3 and EPA is responding accordingly. Real-world exposures involve simultaneous contact with multiple pollutants in addition to PM and O3 that may significantly alter the attributable risks. With policy moving in the direction of considering multi-pollutant interactions, ORD is developing a coordinated research effort in consultation with OAR to link sources of air pollutants to health and environmental outcomes to support air quality management decisions by Federal, State and Local air pollution control agencies.

Although the transition to a multi-pollutant approach is a new effort, the Source-to-Health Outcome/Multi-pollutant research summarized above has resulted in positive impacts and outcomes. Near-road research has produced data and findings that were used to support the 2007 Mobile Source Air Toxics rule (see client poster presented by Cook et al.) and is also being used to develop and improve line source characterization in existing dispersion models, such as AERMOD. Through the PM Centers, the Southern California Particle Center (SCPC) published findings from research studies describing how concentrations of ultrafine particles vary with distance from a freeway in conjunction with the California Children's Health Study in examining how proximity to roadway affects the respiratory health of children. These studies, together with those supported by the California Air Resources Board and other funders, were influential in the development of a new California state law prohibiting the construction of new schools within 500 feet of freeways. In addition, ORD dynamometer research on pollutant mixtures emitted from motor vehicles has been used in the development of the improved motor vehicle emissions simulator (MOVES) model (see client poster presented by Cook and Baldauf). These improved modeling tools will allow EPA to better estimate impacts of traffic emissions on near-road air quality for regulatory analyses of risk and to inform urban transportation planning.

Results of the multi-pollutant research are being used by OAQPS to characterize the benefits of and inform a multi-pollutant risk reduction strategy in Detroit, MI (see client posters presented by Possiel (Poster 1-36) and Jenkins (Poster 2-15)). The objective of this project is to develop a comprehensive air quality management plan in consultation with state, tribal, and local agencies. The multi-pollutant approach being taken by OAQPS confirms the need to provide a better understanding of the complex interactions of multiple pollutants originating from direct source emissions and atmospheric transformations. In addition, ORD's Clean Air Research program and the Ecosystem Services Research Program have been instrumental in aiding the first-ever multi-pollutant NAAQS review for ecological effects associated with NO_x and SO_x (see client poster presented by Rea (Poster 2-16)).

Accountability research is in the early stages of development with the intent to evaluate the effectiveness of air quality management actions and provide iterative feedback to potentially modify regulatory actions. This type of assessment is now recognized as an important consideration in the decision-making process. The accountability assessment typically occurs after actions have been taken to determine their effectiveness. Coordinated research is taking place in the Clean Air Research program and through HEI to address the challenges of determining the benefits to public health of air quality regulations. The results of this research are beginning to show that improvements in air quality are associated with public health benefits. As these studies progress, researchers and policy makers will have a broader set of indicators with which to evaluate the effectiveness of actions taken to improve air quality.

5.0 Future Directions

The Source-to-Health Outcome/Multi-pollutant research performed in the Clean Air Research program will continue to reflect our client's needs to support the development of effective air quality strategies. Future research will address pressing challenges in our understanding of the complexities of a multi-pollutant approach to air quality management. Research will be conducted to elucidate the important interactions between constituents of multi-pollutants that alter the composition and toxicity of the mixture of air pollutants. Risks associated with multi-pollutant exposures need to consider the combined effect of multiple pollutants and their interactions instead of treating co-pollutants as confounders or assuming that effects from multiple pollutants are additive. Multi-pollutant research is needed that is directed at:

- Regional differences in air pollutant risk
- Identifying and characterizing the origins of multi-pollutant atmospheres that harm human and ecological health
- Identify local-scale impacts from near-road and other near-source emissions to identify associations among source characteristics, air quality impacts, and adverse health effects
- Identifying susceptible subpopulations at increased risk of adverse health effects from exposures to multi-pollutant atmospheres
- Developing data analysis techniques to relate the health effects of simultaneous exposures to multiple pollutants including their potential and realized interactions

- Additive and synergistic interactions of pollutants
- Role of climate change altering multi-pollutant atmospheres and vice versa

The multi-pollutant approach in the Clean Air Research program is an integrated effort involving both intramural and EPA-funded extramural research to support our client's needs. Research clearly is needed to understand relationships among air pollutants (PM hazardous components, co-pollutants, and HAPs) emitted from emission sources and the resulting ambient concentrations and transformation products that may be involved in human exposures and adverse effects. Although ORD's multipollutant research is not limited to near-road exposures, it was identified by OAR as a central theme in the Clean Air Research MYP as a problem of pressing interest. A new intramural and extramural near-road research program is underway to improve our understanding of the type and severity of health outcomes associated with near-road exposures and the factors associated with roadways that may impact public health. The STAR program has recently awarded a cooperative agreement between ORD and the University of Michigan to study different types of traffic-associated pollution and impacts on asthma, respiratory viral infection and the biological mechanisms by which exposure to traffic may induce more severe asthma attacks in children. Following a review in October, 2008, EPA's Science Advisory Board concluded the PM Centers program was very successful and should move in a direction consistent with a multi-pollutant approach. The STAR program plans to announce an RFA for Clean Air Research Centers by this summer.

Research on the origin, effects and interactions of multi-pollutant atmospheres will provide critical information to guide the development of future air quality management decisions in consideration of climate change. OAR has identified this as an important priority (see poster presented by Jenkins) and ORD's Clean Air Research program will embrace the climate-air quality scenario in full collaboration with the broader Global Research program as a natural extension of Clean Air Research program's multi-pollutant research effort. The health impacts in the changing exposure paradigm of PM, ozone, and likely other atmospheric transformation products (e.g., aldehydes associated with biofuels and other fuel / energy alternatives) are the focus of speculation and program office concern. Only through the multidisciplinary collaboration of intramural scientists and cooperators will this emerging issue be adequately addressed.

Poster # LTG 2-01

What impact do mobile sources have on near-road air quality and human exposures?

Presenter: Rich Baldauf, US EPA Office of Research and Development

Poster Summary: In recent years, a large number of health studies have identified increased risks of adverse health effects for populations spending significant time near major roads. Air quality studies have found elevated concentrations of pollutants emitted directly by motor vehicles near large roadways, when compared to overall urban background concentrations. The magnitude and extent of elevated concentrations can vary depending on traffic activity, environmental conditions, topography, and presence of roadside features.

The goals of this research program focus on characterizing the impacts of traffic on near-road air quality and human exposures. Results of this work will inform research identifying the relationship of these air quality and human exposures on adverse human health effects. Utilizing an array of state-of-the-art monitoring, wind tunnel, and modeling techniques, researchers characterized the complex mixture of pollutants (gas and particle phases) on/near heavily-traveled highways, the relationship of traffic activity and meteorology on these near-road pollutant concentrations, the impact of motor vehicle emissions on indoor environments and exposures, and the effects of roadway design and roadside barriers on near-road pollutant concentrations.

The data provided an increased understanding of the complex mixture of pollutants present and the relationship between traffic, environmental conditions, distance, and roadway design on air quality and human exposures. Concentrations of a number of pollutants, including CO, black carbon and particle number, were highly elevated on/near the road and decreased exponentially with distance from the road. Pollutant concentrations generally decreased to upwind levels within a few hundred meters although nighttime concentrations can remain elevated at distances up to one thousand meters. For PM, the volatile component more rapidly decayed in concentration with distance compared to non-labile PM species (e.g. EC) or gaseous co-pollutants (e.g. CO, NO_x). Measurements indicated that volatile PM may be present in the gas phase in indoor environments, causing particle shrinkage and/or evaporation during infiltration. The configuration of the road (e.g. at-grade, depressed, or elevated) and presence of roadside features (e.g. noise barriers, vegetation, buildings) also influenced the initial concentrations and gradients of pollutants.

Impacts and Outcomes: A better understanding of the complex mixture of gaseous and PM pollutants near roads allows for the identification of potential causes of reported adverse health effects associated with near-road pollutant exposures. Data from this research provide the foundation for improved emissions and dispersion models for regulatory applications and exposure assessments. The data are also used to suggest new regulatory or voluntary control programs to protect public health and welfare; whether from new vehicle emission standards or urban planning considerations. Detailed chemical and physical data on ambient VOC and PM size-fractionated concentrations may also allow for refined source apportionment assessments to estimate the impacts from heavy- and light-duty vehicles.

Future Directions: Goals for future research include: 1) determining regional and seasonal variations in traffic emission impacts on near-road air quality and exposures; 2) providing improved models to account for local-scale emissions, transport, and dispersion of traffic emitted pollutants for regulatory and exposure assessments; 3) quantifying the potential role of roadway configuration and roadside features on mitigating near-road air quality and exposure impacts; 4) evaluating how gas and PM exposures and toxicity vary with location, season, and particles size; 5) determining the physical and chemical properties of atmospherically processed PM from real-world sources, including secondary formation; and 6) assessing the contributions of traffic emissions to indoor (buildings and vehicles) exposure and toxicity.

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Poster # LTG 2-02

What Health Effects Result From Exposures to Mobile Source Related Air Pollutants?

Presenter: Lucas Neas, US EPA Office of Research and Development

Poster Summary: Prior to the last BOSC review in 2005, toxicologic, clinical and epidemiologic studies had begun to indicate the importance of exposures to mobile source related air pollutants to human mortality and morbidity. Since that review, EPA-supported research has provided additional insights into the magnitude of this health impact on events of public health importance, on clinical measures of pulmonary and cardiovascular function, on reproductive outcomes, on childhood respiratory conditions, on adult lung function, and on neurologic and cognitive development. In a research field with substantial independent involvement by European and Asian scientists, EPA-supported research has made significant scientific contributions. Recent EPA-supported epidemiologic and clinical research has improved our understanding of the role of mobile source-related air pollutants to temporal and spatial variations in mortality and hospitalization, particularly the substantially greater importance to cardiovascular mortality of within-city air pollution gradients over regional gradients. EPA-supported experimental studies have elucidated the roles of diesel exhaust particles, ultrafine particles, and coarse particles from near-road locations on pulmonary inflammation and cardiovascular function.

A key issue of scientific uncertainty for risk assessment is the ascription of these mobile source related health effects to inhaled toxicants such as particulate matter and gaseous co-pollutants, or to other factors, such as traffic noise or stress. Recent EPA-supported studies have addressed this issue by examining both factors simultaneously and by elucidating the underlying biology of the association. Panel studies with repeated clinical measurements of biological indicators have begun to reveal the underlying pathophysiological pathways linking inhalation exposures to mobile source related air pollutants to extremely rapid changes in endothelial and cardiac function.

Impacts and Outcomes: An improved understanding of the specific etiologic factors underlying the now well-established association between mobile source related air pollutants and adverse health events is essential to our collective response to this public health problem. This exposure, particularly proximity to traffic, has considerable implications for environmental justice, for EPA's Smart Growth initiatives and local urban planning, and for local decisions regarding the location of public facilities, particularly public schools, in urban areas.

Future Directions: The general research direction in this field will be increased attention to the underlying etiologic pathway through repeated measures of biologic indicators assessing the health effects of both short-term and long-term exposures; the careful distinction the roles of inhalation and potential traffic-related factors unrelated to air pollutants; to the improved assessment of non-cardiorespiratory health endpoints, such as cognitive development; and to the elucidation of the primary etiologic agents through improvements in human exposure assessment in observational studies and through carefully designed experimental studies.

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Poster # LTG 2-03

What are the impacts of stationary and area sources of air pollution on air quality and human exposures?

Presenter: Janet Burke, US EPA Office of Research and Development

Summary: Effective air pollution control strategies need to consider the impact of air pollution sources on air quality, human exposures, and health effects. ORD has conducted research on the impact of different stationary and area sources on air quality and human exposures using a multipollutant approach that measured PM size ranges (coarse, fine, ultrafine) and chemical composition (elements, ions, organics), relevant criteria gases, and air toxics. This research has characterized emissions, assessed spatial and temporal variation in air concentrations, and identified the relative contributions of these sources.

Studies of the impact of local and regional power plant and industrial sources on air quality have been completed in several U.S. locations with varying source complexity. The impact of coal-fired power plants was evaluated in two different airsheds (Steubenville, OH and Tampa, FL) using comprehensive source profiles, high time resolution sampling/analytical methods, and advanced ORD multivariate receptor modeling tools. A study performed in St. Louis included source profile measurements at an integrated steel processing point source and high time resolution samples at the EPA Midwest Supersite. Impacts of local industrial sources and regional contributions from biomass burning were evaluated with ORD multivariate receptor modeling tools for St. Louis, as well as for a study of industrial point sources in Dearborn, MI.

Airports and shipping ports are also important sources of air pollutants. The impact of the Los Angeles International airport on populated areas was evaluated using mobile monitoring with real-time data collection of particle size, black carbon and particle PAHs, as well as NO_x.

ORD has also advanced air quality modeling tools to quantify the contributions of different emission sources for specific areas within the modeling domain. One example is the CMAQ model with carbon apportionment (CMAQ-CA) that tracks size, composition and source of primary organic and elemental carbon from stationary industrial sources and biomass combustion/wildfires, in addition to mobile sources.

A study to assess the impact of various local and regional sources on human exposures was performed in Detroit, MI. The Detroit Exposure and Aerosol Research Study (DEARS) involved residential measurements of PM mass, elemental and organic PM species, and air toxics in areas expected to have contrasting impacts from local sources. Receptor modeling tools have been used to quantify the impact of both steel and other industrial sources and their differential impacts on the DEARS study areas.

Impacts and Outcomes: ORD's research on the impact of stationary and area sources on air quality and human exposures has demonstrated the importance of a multipollutant approach that characterizes emissions and spatial/temporal variability in concentrations using high time resolution methods, and identifies their relative contributions using advanced modeling tools.

Future Directions: The Cleveland Multiple Air Pollutant Study (CMAPS, 2009-2010) will expand on this research by using high time resolution sampling/analytical methods at multiple locations to quantify the relative impacts of different sources across Cleveland. Research is also planned for relating sources to health outcomes using samples from Steubenville, Dearborn, and Cleveland in toxicological studies.

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Poster # LTG 2-04

What Health Effects Result from Exposures to Stationary and Area Sources of Air Pollutants?

Presenter: Michael Madden, US EPA Office of Research and Development

Summary: The types of ambient air pollutants inducing premature mortality and morbidity are still not fully understood. One research strategy supported by ORD is aimed at determining the causal components and the effects associated with the components. Characterizing health effects associated with stationary emission or area sources have merit in terms of providing comparative potencies of these sources. This poster will discuss three potential approaches to address this area of uncertainty. One approach to determining the health effects related to specific sources is to utilize in vivo and in vitro systems to assess effects associated with exposure to specific sources (e.g., combustion emissions of diesel, gasoline, coal, wood and vegetation). These studies have utilized healthy and "sensitive" animal models and human populations to determine susceptibility factors. Another approach is to examine mortality and health effects (e.g., hospitalizations for cardiopulmonary problems) in specific geographical areas (airports, harbor, U.S. regions) where air shed compositions are different in order to potentially associate sources to specific health effects or determine if there are regional differences in health effects that may be associated with different source profiles. A third approach is to examine searchable mortality or health effect databases. To date, health effects have been reported which suggest that specific stationary sources and regional pollution play a role in cardiovascular and pulmonary organ systems, and that PM from different sources is not equally toxic. The differences in the cardiopulmonary toxicity of PM from various sources appear to be due, in part, to the PM chemical composition, and may be modulated due to PM size. Coarse PM from US western metropolitan areas does not seem as potent for mortality as coarse PM from the eastern and central US.

Impacts and Outcomes: Findings from studies which examine health effects associated with source or area specific pollution will assist in determining the causative components and sources of ambient air pollution. These findings will allow risk managers to better assess strategies to minimize health effects from PM exposure with more certainty in their decision making. These findings will provide important information about the health effects associated with exposure to specific sources.

Future Directions: Different stationary sources and area ambient pollution have elicited in several cases specific cardiovascular and pulmonary responses. Further confirmation of effects from pollutants collected in areas where a variety of different emission sources are expected to be strong contributors (e.g., diesel emissions from harbors) are needed. Additionally, further examination of the relative contributions of various sources to health effects observed in epidemiology studies, as are studies which link specific sources or mixtures of sources to adverse health effects observed in susceptible populations, are essential to better define causative components of air pollution. Source apportionment of ambient PM and gases in large U.S. cities (e.g., NPACT) are necessary to identify the most potent PM sources for a specific health effect. "Accountability" studies would potentially indicate if the health hazards identified with a specific pollutant were accurate, and reductions in said pollutant were effective. In addition, similar study approaches (e.g., HEI ACES program) can be utilized to examine effects of exposure to specific sources that are subject to changing technology, e.g., new compression and spark ignition engines.

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Poster # LTG 2-05

What Effect Does Atmospheric Chemistry Have on Air Quality and Human Health Effects?

Presenter: Michael Kleeman, University of California at Davis

Poster Summary: Recent laboratory experiments provide evidence that chemical transformations increase the toxicity of airborne particulate matter (PM). Concentrated ambient particle (CAPs) studies in central California strongly suggest that aged PM induces stronger health effects than fresh PM. The dominant chemical transformations that influence the toxicity of PM are not clear but these results point to the need to further examine the role of atmospheric chemistry. Recent studies show that secondary sulfate particles in combination with ozone are associated with increased mortality. In contrast, our understanding of chemical transformations for organic aerosols and potential health effects is still developing. The primary organic aerosol (POA) that was traditionally viewed as non-volatile has been shown to be at least partially semi-volatile. Recent apportionment studies using organic molecular markers for POA and SOA achieve reasonable mass closure at multiple locations in the Midwestern US. These calculations already predict that secondary organic aerosol (SOA) concentrations rival POA concentrations. A semi-volatile POA fraction will further increase the ratio of SOA/POA. The implied bias in current calculations may be offset by the possibility that organic molecular markers decay over time leading to reduced POA estimates in current calculations.
One of the leading theories put forward to explain the toxicity of aged PM is production of reactive oxygen species (ROS). New automated techniques to measure ROS, as well as newly applied techniques that quantify individual ROS species, provide the opportunity to test this hypothesis. It is likely that atmospheric chemical transformations enhance the ROS formation potential of PM and other atmospheric oxidants. Ultrafine particles ($Dp<0.1\mu m$) adjacent to freeways are dominated by primary emissions from motor vehicles but atmospheric chemical reactions may result in the development of higher concentrations of oxygenated organic species with unknown implications for toxicity. These near-field chemical reactions likely involve heterogeneous reactions between particles and gas-phase oxidants.

Impacts and Outcomes: The finding that aging increases PM toxicity highlights the need for SOA apportionment tools. The ability to explain SOA production using molecular markers will help identify relevant SOA mechanisms that can be used for the design of emissions control strategies. The realization that POA is at least partially semi-volatile and that molecular markers may react in the atmosphere has catalyzed a great deal of critical review for traditional source apportionment calculations applied in regions heavily influenced by long-range transport.

Future Directions: The SOA source apportionment techniques demonstrated in the Midwestern U.S. should be applied in California to determine if SOA may also be formed in a region that is not dominated by biogenic emissions. Toxicology studies which employ updated source apportionment techniques are needed to estimate SOA concentrations during human and animal exposures. Studies are needed that measure OH and H_2O_2 generation by PM to determine whether toxicity is linked to ROS formation and oxidative stress.

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Poster # LTG 2-06

How Can Simulated Atmospheres Be Used To Understand The Impact Of Atmospheric Processes On Air Quality And Human Health Effects?

Presenter: Petros Koutrakis, Harvard EPA PM Center

Poster Summary: Particulate and gaseous source emissions undergo many transformations once released into the atmosphere. It is quite likely that secondary and primary pollutants exhibit different toxicities. Since most of the source-specific toxicity studies to date have focused on primary pollutants, there remains a great need to investigate the relative toxicity of source-specific primary and secondary particles. Recently, several US research groups have begun to investigate the impact of atmospheric processes on air pollutant toxicity. These studies use photochemical chambers to age source emissions which are subsequently characterized for their physico-chemical and toxicological properties. Below we provide a brief description of some of these investigations: 1) The Harvard Toxicological Evaluation of Realistic Emission Source Aerosol (TERESA) study which investigated the relative toxicity of primary and secondary PM emissions from coal-fired power plants, *in situ.* Stack exhaust was transported to the photochemical chamber in which different atmospheric processes were simulated, including oxidation and neutralization. Pinene was also added to simulate oxidation of both power plant and biogenic emissions. Sprague-Dawley rats were exposed and were evaluated for pulmonary, systemic, and cardiovascular effects. 2) HEI sponsored a study with the Desert Research Institute and the Lovelace Respiratory Research Institute to examine how atmospheric transformations altered gas- and particle-phase diesel emissions under the influence of sunlight, O_3, and OH and NO_3 radicals, and explored changes in biological activity. The biological activity of PM was evaluated in rodents and mice using pulmonary toxicity, inflammation, and oxidative stress responses. 3) Finally, UNC researchers used a smog chamber for exposures that examine the toxicological potential of air pollution mixtures. These studies used *in-vitro* systems to expose A549 cells, an alveolar type II-like cell line, and primary human bronchial epithelial cells, grown on membranous support, which were subsequently analyzed for cytotoxicity and cytokine gene expression. The HEI study showed that chemical composition varied markedly with both the degree of processing of the engine emissions (i.e. aging) and the presence of co-reactants. The results suggested that toxicity increased when OH radicals or additional VOCs were present. Furthermore, findings from the TERESA study suggest that increasing particle complexity through photochemical reactions and addition of pinene and ammonia enhanced particle toxicity. Finally, particles produced through photochemical reaction of power plant emissions were less toxic than Boston Concentrated Ambient Particles studied previously.

Impacts and Outcomes: Individuals are often exposed to source emissions which have undergone photochemical transformations in the atmosphere. These aging processes alter the physical and chemical properties of the primary pollutants and consequently are likely to affect their toxicity. The atmosphere is an oxidizing medium which converts many of the primary pollutants to more reactive species e.g. oxygenated hydrocarbons, acids and radicals. Therefore, improving our understanding of how atmospheric transformation impacts toxicity is of paramount importance in our efforts to regulate air pollution sources.

The type and amount of reactants, aging time, and light intensity used with photochemical chambers can be varied to simulate different atmospheric conditions. These different realistic exposure scenario atmospheres can then be tested for differences in toxicity. Therefore it is possible to investigate how increasing or decreasing the emissions of a primary pollutant (e.g. NO_x) could influence the toxicity of human exposures. This information can be critical for the development of sound SIPPs.

Future Directions: The TERESA approach formed an excellent foundation for future research, as it can readily be adapted to investigate other combustion sources. Using these technologies, the Harvard group will investigate the toxicity of primary and secondary pollutants from mobile source “fleet” emissions collected inside the ventilation stack of a large roadway tunnel in the Eastern U.S. Additionally, scientists from EPA-ORD are designing a dynamic mode (steady-state) photochemical reaction chamber that will be coupled with pilot mobile and stationary (industrial) emission sources and a set of small animal exposure enclosures. These studies will include a systematic toxicological characterization of the primary and secondary pollutants emitted from a variety of sources and the effects of atmospheric transformations.

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Poster # LTG 2-07

How Can Source-Receptor Models be Used to Understand the Relationship Between Sources and Effects of Multiple Air Pollutants?

Poster Presenter: Rachelle Duvall, US EPA Office of Research and Development

Poster Summary: Receptor models are used to evaluate and quantify sources of air pollution using chemical speciation measurements. Source contributions from these models can be used to evaluate the relationship between sources and health effects. The receptor models vary in complexity and data requirements and include Chemical Mass Balance (CMB), Absolute Principal Component Analysis (APCA), Positive Matrix Factorization (PMF), and Unmix. The results from these models have been used in both toxicology and epidemiology studies to evaluate the association between air pollution and health effects.

In the Multiple Air Pollutant Study (MAPS), the CMB model was used to apportion fine PM sources and these results were evaluated against toxicological assays. Mobile sources and secondary sulfate from coal combustion were related to increases in lung inflammatory markers *in vivo* and *in vitro*. Another study used PMF and CMB to apportion fine PM collected in Atlanta, GA. Emergency department cardiovascular visits were associated with mobile sources and biomass burning, and secondary sulfate was associated with respiratory disease visits. Many source-receptor models can be used to apportion PM sources, and results can potentially differ by user or method. However, independent studies demonstrated similar source apportionment results when the same data set was analyzed by multiple users and multiple source-receptor models applied to health effects analyses. Similarly, many methods can be used to relate health and epidemiology effects to PM sources. The range of epidemiologic results among multiple users and methods has been evaluated in two studies. In these studies, secondary sulfate in Washington, DC and Phoenix had the most consistent association with cardiovascular mortality.

Most studies examining health effects and sources have focused on speciated PM data available from State or National Networks. Other studies have used additional particle characteristics in their receptor modeling analysis. Recently, particle size distribution data was successfully apportioned into contributing sources using PMF and these results will be used in an evaluation of health outcomes. In addition to the receptor models mentioned above, Scanning Electron Microscopy (SEM) and classification methods have been used to identify particle classes/source types. In a study in which human subjects were exposed to coarse concentrated particles (CAPS), there were increases in lung inflammation, changes in various blood markers, and changes in autonomic control of heart rate. XRF and SEM/EDX are currently being used to link these changes in health end points with specific PM components/sources.

Impacts and Outcomes: Studies utilizing source-receptor models to understand the relationship between sources and health effects provide insight into the role of air pollution sources on human health effects. We have a better understanding of the relationship between PM sources/particle classes and both toxicology and epidemiology effects. These research efforts will continue to support EPA's development of effective air pollution standards and regulations.

Future Directions: Future plans for this research involve application of receptor modeling techniques using different types of data (e.g. particle size distribution data, high time resolution data, etc.) and multiple air pollutants (CO, SO_2, NO_2) for health effects analyses. National speciated monitoring networks, monitoring intensives, sample collection for toxicological studies, and CAPS studies of ultrafine, fine, and coarse particles will provide detailed speciation data that will allow for further evaluation of the relationship between sources and health outcomes. In addition Bayesian and other statistical methods are being developed for determining the association between sources and health outcomes.

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Poster # LTG 2-08

Is There Evidence that Short-Term Effects of PM on Mortality and Morbidity Vary Across Geographical Locations?

Presenter: Francesca Dominici, PhD; Johns Hopkins University Department of Biostatistics

Summary: Multi-site time series studies have provided strong evidence of increased risk of mortality and morbidity associated with short-term exposure to levels of various indicators of airborne particles, including the current regulatory indicators of particulate matter (PM) with an aerodynamic diameter $\leq$10 microns (PM_{10}) or 2.5 microns ($PM_{2.5}$). These studies use the same standardized protocol for estimating risks at the different locations, thus providing more informative findings than meta-analytic summaries. In addition, it is possible to maintain an ongoing collection of time-series data into a single data set so that similar analyses could be carried out periodically. Recent multi-site time series studies in the USA, Canada, Europe and Asia suggest that the short-term effects of PM on mortality and morbidity vary by geographical regions. For example, a recent multi-site time series study of hospital admissions and daily $PM_{2.5}$ levels in Medicare enrollees, found strong regional patterns of effect across the 204 U.S. counties included. Effect estimates for some cardiovascular causes were statistically significant in the eastern U.S., but not in the western U.S. Short-term effects of PM_{10} on total non-accidental mortality were larger in the Northeast and in summer. In the Air Pollution and Health: A European study (APHEA), effect estimates for particles and mortality were lower for central-Eastern Europe than Western Europe, although more recent work suggests these differences are explained in part by choice of statistical modeling. There is a large body of literature investigating effect modification of short-term effects of PM on mortality morbidity. Some studies have found that geographical variability of the adverse health effects of PM might be explained by weather, socio-economic variables, and by the chemical composition of PM.

Impacts and Outcome: Multi-site time series studies and investigation of effect modification provides additional insight about how location-specific factors such as extreme temperatures, social class, susceptibility, PM chemical composition, and local emission sources might explain the geographical heterogeneity of the air pollution relative risks. Understanding the effect modifiers of the short-term effects of PM will lead to more efficient and targeted strategies for air pollution control. For example, it is well known that chemical composition of the PM components of the particle mixture varies regionally. If the chemical composition of particles affects toxicity, we would expect to find evidence of regional heterogeneity in the short-term risks associated with the $PM_{2.5}$ total mass. The presence of heterogeneity could result from variation in the toxicity of chemical constituents of particles, the nature of the air pollution mixture and the presence of possibly confounding pollutants, or differences in the underlying populations' susceptibility.

Future Directions: Efforts to focus policies aimed at protecting human health from ambient PM exposure are limited by current scientific understanding of effect modification, such as the toxicity of various components of the PM mixture and of the sources that contribute injurious particles. The principal limitations in interpreting the results of these analysis lie with the data available to the investigators, and with the degree of measurement error attributable to geographical aggregation of the data. Additional studies need to be conducted to further investigate the effect modifiers identified in these large-scale studies. These studies needs to target specific sub-populations, geographical regions, and collected and analyze data at individual level.

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Poster # LTG 2-09

What Impact do Multiple Sources Have on an Airshed?

Presenter: Gary Norris, US EPA Office of Research and Development

Poster Summary: A complex mixture of local, urban, and regional PM and volatile sources contribute to the air pollution in an airshed, presenting a challenge to separate sources and to identify which sources contribute to the measured air pollutant concentrations. Understanding the relative contribution of these sources is important because exposure studies have demonstrated differential residential outdoor to indoor infiltration of sources and health studies suggest relationships between sources and health outcomes can vary by source. In addition, air quality management decisions require air pollution source information to develop control strategies.

ORD is identifying and quantifying sources of air pollution with an integrated approach focused on reducing the uncertainty in the apportionments through a combination of sampling, analytical and model development, and application in non-attainment and human exposure studies. Sampling development and evaluation has focused on both high time resolution sampling methods to identify local and urban PM sources (< 12 hours), and low time resolution sampling methods to evaluate spatial variability of PM sources (72 hours to one week). Analytical methods development has been primarily directed at quantifying detectable source markers using these sampling methods (ICP-MS, scanning electron microscopy energy dispersive XRF, GC-MS PM organic speciation, GC-MS/GC-FID VOC speciation). Receptor model development has focused on development of the EPA Positive Matrix Factorization (PMF), EPA Unmix, and EPA Multilinear Engine Human Exposure multivariate receptor models, and the Air Pollution Transport to Receptor (APTR) hybrid tool which links composition and receptor model results with meteorology to identify the geographical areas of the contributing sources.

Impacts and Outcome: The sampling, analytical, and modeling tools have been applied in human exposure studies performed in a number of urban areas across the U.S. that vary in terms of source complexity and studies in Midwest urban areas with complex airsheds containing multiple local sources. The human exposure studies identified residential outdoor, indoor, and personal sources as well as infiltration rates for sources. Data from studies performed in complex urban areas will be used for development of local air pollution control strategies and the source profiles, methods and model development are critical for ORD's future source apportionment studies. The modeling techniques have also been used to determine contributions from multiple sources near the World Trade center following the 9/11 terrorist attacks.

Future Directions: Future efforts to address this question are focused on the 2009 to 2010 Cleveland Multiple Air Pollutant Study (CMAPS) with the following goals: quantify sources using a combination of high time and low time resolution sampling and EPA receptor modeling tools to identify local and regional sources contributing $PM_{2.5}$, coarse PM and Hg and provide these findings to the Cleveland Division of Air Quality, State of Ohio, and EPA Region 5 for developing air pollution control strategies; evaluate the relationship between sources and health markers; evaluate combined air quality modeling (CMAQ + AERMOD) and use the results to improve the emission inventory; and identify new research areas that will further reduce uncertainty in source apportionment. In addition, ORD's source apportionment research will focus on data already collected in the Detroit Exposure and Aerosol Research Study and near-road studies.

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Poster # LTG 2-10

How Effective are Airshed/Sector-Specific Regulatory Actions?

Poster Presenter: Valerie Garcia**,** US EPA Office of Research and Development

Poster Summary: The impact of regulations on air quality has historically been estimated by tracking trends in emissions and ambient air concentrations. Currently, EPA is exploring the potential of measuring impact along the entire source-to-outcome risk continuum. Assessing whether air quality management activities are achieving their intended results requires (1) developing indicators that reflect changes in source emissions, ambient air concentrations, exposures, and health outcomes and (2) characterizing the processes that impact the relationships among these indicators. To address these objectives, EPA is conducting several studies to examine the relationship between reductions in emissions and changes in ambient pollutant concentrations. This focus on source-specific emissions requires consideration of multiple pollutants as sources typically emit a suite of pollutants. Understanding the interactions of these pollutants is critical in assessing the source and the health impacts of multiple air pollutants in an air parcel downwind of the original source. Intervention studies have been performed to assess the impact of local air quality policies. For example, some studies are evaluating the effect of significant reductions in mobile source emissions resulting from the Atlanta and Beijing Olympic Games, while another study is examining the change-out of woodstoves in Libby, Montana on fine particulate matter concentrations during the winter. On the health end of the risk continuum, several studies are examining the use of chemical and genetic biomarkers of exposure, and to characterize susceptibility. While many of these efforts are focused on local-scale impacts and are addressing linkages across part of the risk continuum, other studies are spanning the entire source-to-outcome continuum. A recent study examined the association between the reduction in fine particulate matter and changes in life expectancy across 51 US metropolitan areas, while a regional scale study is examining the impact of the NOx SIP Call on respiratory-related hospital admissions in the state of New York.

Impacts and Outcomes: The results of these studies provide insights into the effectiveness of emission control actions implemented to protect human health. Such iterative feedback allows for additional corrections, if needed, and reveals those approaches that are most effective at meeting their objectives. The development of indicators, such as suites of source-specific pollutant species and mixes, and chemical and genetic biomarkers, advance the methodologies that can be used in subsequent studies, providing consistency in studies conducted across geographic areas and spanning across multiple years. Finally, this research provides invaluable insight about physical and chemical processes and how these processes interact to produce the outcomes ultimately measured in the environment.

Future Directions: While we have made significant progress in advancing our understanding of how emission control actions change ambient pollutant concentrations, more research is needed to understand the complex interactions of multiple pollutants and their effects on human health. In pursuit of this goal, research to identify sector-specific emission sources from the chemical composition of an air parcel will be critical in linking control actions with ambient pollutant concentrations, human exposures and health impacts. In addition, continued research will be needed to identify chemical and genetic biomarkers that characterize exposure to pollutants of concern, and to develop health indicators that can be traced back to pollutant exposures for use in surveillance tracking, epidemiology studies and risk assessments.

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Poster # LTG 2-11

Are there combined effects of multiple pollutants - synergistic, additive or antagonistic?

Poster Presenter: Kent E. Pinkerton, University of California, Davis

Poster Summary: Environmental air pollutants are composed of a complex mixture of substances in the form of gases, vapors and solid particulates. Environmental exposures are not to single pollutants, but rather to a mixture of air contaminants that change over time and location. A number of studies funded under EPA's air pollutant research program are beginning to elucidate the effects of combined environmental pollutants to impact potential health outcomes. Synergistic effects between ozone and other pollutants have been demonstrated in studies involving humans and animals. Mauderly and Samet found in a number of studies testing for synergy that greater than additive effects were observed for one or more outcomes. The co-pollutants in these studies included particulate matter, cigarette smoke, sulfuric acid, nitrates, nitrogen dioxide, peroxyacetyl nitrate, endotoxin, and antigen (Mauderly and Samet, 2009; Yu et al, 2002). Human laboratory studies with concentrated fine particulate and ozone to date have failed to demonstrate interaction to alter cardiovascular conditions, compared to PM alone (Brooks et al, 2008). In contrast, studies of ambient ozone and mortality have shown secondary sulfate particles to influence mortality in combination with ozone, while no association with fine particulate mass has been observed (Bell et al, 2007; Franklin et al, 2008). Long-term exposure to lead has been shown to synergize to a greater degree ozone sensitivity in cardiac autonomic dysfunction observed as reduced heart rate variability (Park et al, 2008). Studies to examine birth outcomes have suggested ozone, carbon monoxide and particulate matter have different health impacts, based on timing and co-pollutant interactions during pregnancy (Salam et al, 2005). Studies in laboratory animals and humans suggest potential synergy for particles based on their composition to elicit stronger combined effects. Such synergism has been noted with soot, transition metals, as well particle composition based on distance from roadways (Pagan et al., 2003; Zhou et al, 2003; Pinkerton et al, 2004; 2008; Medina-Ramon et al, 2008).

Impacts and Outcomes: Studies to examine interactions that may lead to altered health outcomes could be described as additive, synergistic or even antagonistic. There is growing interest in better understanding the overall interaction of multiple pollutants to create the most beneficial conditions for public health. As a better understanding of the combined effects of multiple pollutants and their interactions is achieved, we can begin to better manage pollutants to maximize the overall health benefits.

Future Directions: 1) Determine which pollutants act in an additive or synergistic fashion, 2) better understand the confounding effects of other pollutants when testing single pollutant effects, 3) elucidate those conditions in which synergism between pollutants may occur, 4) evaluate the potential for the interaction of pollutants to impact on susceptible populations, including children, elderly and individuals with cardiopulmonary and/or immune compromise, 5) determine potential of multiple pollutants to impact on specific anatomic regions and target cell populations, i.e., airway and alveoli, myocardium, epithelium, macrophages, endothelium, etc.

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Poster # LTG 2-12

What Are Exposures To Multiple Pollutants In An Airshed?

Presenter: Ron Williams, US EPA Office of Research and Development

Poster Summary: Humans are simultaneously exposed to multiple sources of air pollutants each day. These sources produce pollutants ranging from particulate matter (PM), volatile organics (VOCS), semi-volatile organics (SVOCs), and other gas-phase pollutants. While ambient-based measurements are available for many of these pollutant species, little information exists on indoor concentrations and personal exposures to multiple pollutants. Answering this research question requires a coordinated effort involving both real-world human exposure studies as well as controlled laboratory experiments. Research efforts like the Detroit Exposure and Aerosol Research Study (DEARS) and the Relationships of Indoor, Personal and Air (RIOPA) study among others, are evaluating the relationships between personal exposures and ambient concentrations of multiple pollutants that originated from a variety of sources. The RIOPA study involved measurements at 100 homes with 100 adult residents in each of three cities with different air pollution sources and weather: Los Angeles, CA; Houston, TX and Elizabeth City, NJ. The DEARS was conducted in a single airshed containing multiple industrial and mobile sources. In both studies, homes were selected based on proximity to industrial and/or mobile sources and involved the collection of 1-day (DEARS) and 2-day (RIOPA) measures of personal, residential indoor and outdoor, and ambient-based measures for PM, VOCs, SVOCs and gaseous co-pollutants. These studies were performed in conjunction with controlled experiments in ORD's test chambers and research test house, and in controlled experiments conducted by external collaborators. These investigations focus upon reducing uncertainty in estimating key model parameters for penetration, indoor surface interactions, particle resuspension, and transport into the breathing zone. Results of these studies have been used to improve estimates of local and regional sources on population exposure and improve strategies for reducing indoor exposures to air contaminants. In addition, these data have been used to improve predictive capabilities of exposure models to represent national, regional, and local population-based human exposures in both indoor and outdoor environments.

Impacts and Outcomes: Results from these studies will be used to assess the factors affecting and relating to multipollutant exposures originating from a variety of sources. Real-world and controlled studies are providing the means to provide critical data to model the uncertainty of ambient-based surrogates of human exposures. Such data is needed to improve epidemiological findings linking community-based measures of multiple pollutants to observed human health effects and to inform for local, regional and national risk management decisions.

Future Directions: Field work and data findings have been completed for the RIOPA studies. Data analyses and reporting on the DEARS have begun. Test house and chamber data analyses are in progress and work is continuing to investigate source emissions and sink effects of key air toxics, such as formaldehyde.

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Poster # LTG 2-13

What is the relative toxicity of air pollutants from different sources?

Presenter: Anthony Wexler, San Joaquin Valley Aerosol Health Effects Research Center, University of California, Davis

Poster Summary: Current National Ambient Air Quality Standards (NAAQS) regulate time-averaged mass concentrations of atmospheric particles. The NAAQS do not control the chemical composition of the particles, their sources, or other physico-chemical properties due to insufficient epidemiological or toxicological evidence. Ambient PM is composed of so-called primary and secondary components. The primary components are emitted directly by their sources as particles and gases whereas the secondary components are emitted as gases and react in the atmosphere to form particulate and other gaseous compounds. The primary components can often be related back to their sources by their chemical signature, especially metals. Some of the secondary components are indicative of certain regional source classes (i.e., sulfates from coal combustion in the eastern US) but other secondary compounds do not indicate a source class (i.e., nitrates derive from a range of combustion sources).

Pollutants disperse and dilute rapidly in the atmosphere so that emissions close to the breathing zone may have much greater health effects than those emitted remotely (i.e., vehicles vs. tall power plant stacks). Air quality in a city is judged by at most a few monitors that cannot capture the variability due to local emissions so that epidemiological studies based on these monitors do not capture local variability. Maynard and coworker (2007) used single-site monitors in Boston plus traffic data to develop a map of local traffic-related pollutant levels. The resulting association between pollutant concentrations on the day before death to the local air pollutant levels on other prior days showed increased all-cause mortality risks due to stroke and diabetes.

Park et al., (2007) used an analysis of air mass history to associate geographical source regions with heart rate variability (HRV). HRV is a highly time resolved indicator of cardiac health so it can be related to the arrival time of air parcels and their chemical constituents. Employing this in Boston, Park and coworkers found HRV-indicated decrements in cardiac health associated with (a) black carbon arriving from the southwest, (b) ozone arriving from the west, and (c) all particulate indicators when the air was local. Their observations also indicate greater health effects for air parcels arriving in Boston from the west and northwest compared to the north.

In laboratory studies, Seagrave et al., (2005) exposed rats to diesel exhaust and hardwood smoke and examined a number of indicators in bronchoalveolar lavage fluid. Results depended nonlinearly on the exposure concentration with some endpoints exhibiting greater effects at lower, atmospherically-relevant concentrations than at higher, and effects that differed between males and females.

Impacts and Outcomes: Current National Ambient Air Quality Standards (NAAQS) regulate the mass of particles in the atmosphere regardless of their source, yet some sources, such as sea spray, are likely to be much less toxic than others, such as diesel exhaust. In addition, the secondary components of PM, such as sulfates and nitrates, are common to many sources, while others, such as metals and soot, are more characteristic of certain sources. Characterizing the health effects of the sources of air pollution (particles and gases), including their primary and secondary contributions, could lead to more stringent regulation of toxic sources and more lenient regulation of less toxic ones thereby improving the cost-benefit ratio of air quality regulations.

Future Directions: The few source-dependent health effects studies that have employed epidemiological techniques suffer from the potential of one pollutant acting as the surrogate for another (Kim et al., 2007). Toxicological studies have been performed on emissions from sources but without atmospheric processing that may increase or decrease the toxicity of these emissions. The mix of air pollutant sources in the United States is a mix of those that are ubiquitous and those that are regionally or locally distinct.

Certain sources such as vehicle and meat cooking prevail in many areas around the country whereas large power production and industrial point source emissions dominate only certain areas of the country. All of these sources contribute emissions that influence secondary formation of air pollutants. Deciphering the health effects of different sources, especially the secondary components, is still in its infancy. New field instruments and laboratory techniques must be developed and deployed to measure these relative toxicities and assign sources to them.

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Poster # LTG 2-14

How can stationary source emissions be reduced using a multipollutant control strategy?

Presenter: Nick Hutson, US EPA Office of Research and Development

Electric Sector Sources

Poster Summary: The EPA issued the Clean Air Interstate Rule (CAIR) in March 2005. The intent of the Rule is to reduce sulfur dioxide (SO_2) and nitrogen oxides (NO_X) emissions in the eastern United States by over 70 percent and 60 percent, respectively, from 2003 levels. To meet the SO_2 reduction requirements, a significant increase in the use of wet Flue Gas Desulfurization (FGD) technology is expected; by 2020, as much as 60% of total coal-fired capacity is expected to utilize some a wet-FGD technology.

Many wet-FGD scrubbers may also be effective in removing oxidized forms of mercury from flue gas. This co-benefit control is only effective, however, for flue gas streams containing oxidized forms of mercury because the elemental form is not soluble. In general, facilities that burn coals with higher chlorine content (as often seen in eastern bituminous coals) tend to produce more oxidized mercury.

With the number of wet-FGD scrubbers scheduled to be constructed in response to CAIR, it is desirable to develop and operate wet scrubber-based technologies to provide simultaneous multipollutant (SO_2, NO_X, and both Hg^0 and Hg^{2+}) control. Such technologies could make wet-FGD scrubbers more cost-effective and could potentially obviate the need for installation of additional costly control equipment for NO_X.

Impacts and Outcomes: In this work, we have studied the addition of an oxidizing agent (a solution of $NaClO_2$) to a typical wet-FGD scrubber to give the scrubber multipollutant control capacity. The work has been conducted using both bench- and pilot-scale equipment. Bench-scale results showed a maximum scrubbing of 100% for SO_2 and Hg species and near complete NO oxidation with about 60% scrubbing of the resulting NO_X species. The chlorite additive was less effective as an oxidant in the absence of SO_2 and NO in the flue gas. Additional studies were conducted over a broad pH range in order to better understand the chemistry of the oxidant addition. Testing identified practical operational strategies for the optimization of the use and performance of the oxidizing additive.

Future Directions: Testing in the bench- and pilot-scale equipment will continue with the emphasis on further understanding the chemistry of the process and on further optimization of the introduction of the oxidant additive.

Industrial Sources

Poster Summary: Industries are also subject to a number of different regulations that target one or more air pollutants. These include New Source Performance Standards (NSPS) for criteria pollutants and Maximum Available Control Technology (MACT) requirements for hazardous pollutants. Application of control measures to meet each of these regulations individually may not be as cost-effective as more holistic approaches. To identify opportunities for achieving more cost-effective reductions, both within and across industrial sectors, EPA has developed the Industrial Sectors Integrated Solutions (ISIS) modeling framework. ISIS currently includes the U.S. cement sector, and is being expanded to include additional sectors, such as pulp-and-paper and iron-and-steel.

Impacts and Outcomes: ISIS has been used to evaluate multi-pollutant control strategies for the cement sector. This modeling, which considered control impacts on multiple pollutants simultaneously (e.g., Hg, SO_2, THC, HCl and PM) was used to support the EPA's recent National Emission Standards for Hazardous Air Pollutants (NESHAPs) efforts. In addition, the framework has been used to demonstrate an evaluation of the impacts of pollutant cap-and-trade programs on the cement sector.

Future Directions: Expansion of ISIS to include additional sectors will enhance EPA's ability to consider multipollutant control approaches both within those specific sectors and across industrial sectors.

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Poster # LTG 2-15

ORD Air Research Supports OAR's Forward-looking Priorities

Presenter: Scott Jenkins, US EPA Office of Air Quality Planning and Standards, Office of Air and Radiation

Poster Summary: OAR programs, which are responsible for some of the largest public health benefits attributable to EPA, rely heavily on products from the ORD Air Research Program to provide the scientific basis for decision-making. In particular, the Air Research Program's focus on characterizing the relationship between pollutant emissions, air quality, and health effects will continue to be critical as OAR responds to recent input from scientific advisory bodies and to new legislative requirements. Three examples are provided here.

- **Air Quality and Climate:** Current research indicates that there are important interactions between air quality and climate. ORD and OAR are working together to improve the understanding of potential interactions between climate, air quality, and health. ORD is developing tools to improve the understanding of the linkages between air quality policies and policies to mitigate climate change through reductions in climate forcing pollutants. Specifically, ORD has initiated research to improve our ability to model the air quality, climate, and health impacts of different future-year anthropogenic emissions scenarios, as well as developing new applications of the MARKAL model focused on understanding the air quality implications of regulations and legislation addressing greenhouse gases.
- **Multi-pollutant:** External expert advisory bodies, including the National Academy of Sciences and the Clean Air Scientific Advisory Committee, have encouraged EPA to consider the ambient mixture when assessing the impacts of individual pollutants. In response to these recommendations, and to requests from OAR, ORD has integrated into its Air research program an overarching framework that incorporates a multi-pollutant perspective. For example, building on the success of the PM Centers, ORD is planning a multi-pollutant focus for an upcoming request for applications (RFA) to fund multiple Clean Air Research Centers. ORD has also initiated efforts to understand the exposures and health effects associated with pollutants found near roadways. In addition, ORD and OAQPS have worked together to characterize the potential benefits of a multi-pollutant risk reduction strategy with a focus on Detroit, MI. All of this work has the potential to provide the scientific basis for incorporating multi-pollutant considerations into standard-setting and implementation decisions.
- **Biofuels:** Under the Energy Independence and Security Act (EISA), EPA is responsible for, among other things, assessing the potential impacts on air quality and health of in increased usage of biofuels. ORD's ongoing efforts to improve CMAQ estimates of secondary organic aerosol formation will form a large part of the basis for OAR's efforts in projecting the potential benefits and/or dis-benefits of increased reliance on biofuels.

Impacts and Outcomes: ORD Air Research is providing the basis for an improved understanding of the relationship between ambient air quality and human health. In April 2008, ORD and OAQPS co-sponsored a workshop to discuss health research priorities for ambient air quality data that would most advance our understanding of the impacts of criteria air pollutant exposures, with a focus on particulate matter (PM). To understand the relationships between air pollutants and adverse health effects, researchers utilize ambient air measurement data collected through monitoring networks operated almost exclusively by State, local, and Tribal air monitoring programs. However, because ambient air monitoring networks do not capture data everywhere or in some cases every day, there remain important uncertainties especially relating to lag-times and other temporal issues with PM-associated outcomes as well as PM component and co-pollutant attributions. With the workshop, ORD and OAQPS sought advice on concrete steps that could be taken to prioritize monitoring sites and/or specific fine particle components for more frequent monitoring in order to facilitate current and future health effects studies and improve comparisons of risk estimates across studies. The workshop served to foster better communication and to facilitate scientific interaction within the air pollution community to gain better and clearer access to relevant data, provide input in monitoring network design, and to develop strategies to begin to acquire the data needed to move our understanding of the potential health impacts of criteria pollutants forward.

Future Directions: OAR continues to work with ORD to better integrate planning and research schedules to help ensure that products from the ORD Air Research Program are available for review and consideration in EPA policy decisions related to these new and advancing priorities. Ideas suggested in the 2008 health research priorities workshop are being developed by groups from OAR and ORD in pilot efforts aimed at the three topics considered here, for example.

Poster # LTG 2-16

ORD Air Research Support to the Office of Air and Radiation for Multi-scale and Multi-pollutant Measurements and Models of Traffic Emissions to Help Characterize Human Health Effects

Presenter: Rich Cook, US EPA Office of Transportation and Air Quality, Office of Air and Radiation

Poster Summary: Over the last several years, ORD has conducted a large-scale research program to better characterize near road air pollution and its impacts on human health. This research has included direct measurements of pollutant gradients near roadways as well as modeling. Work is also underway to better understand the relationship between pollutant estimates from these studies to the adverse health effects that have been observed in numerous studies. In addition, ORD has conducted research on impacts of roadway design on dispersion of pollutants near roads, in order to identify potentially effective mitigation strategies. The measurement studies have shown linkages between traffic intensity, meteorological conditions and near-road concentrations of the pollutant mixture. In addition, measurement data, wind tunnel testing, and numerical modeling have shown that air pollutant impacts near roads can be mitigated by infrastructure design options such as the roadway configuration and presence of roadside structures.

Furthermore, efforts to better model concentrations of pollutants near roads have resulted in substantial improvements in EPA's capabilities to model urban air quality. ORD and OAR staff have developed practical, readily adaptable methodologies to model emissions at the road link level using emission factor models, travel demand models, and GIS data. Methods have also been developed to conduct air quality modeling using a "hybrid" approach, which combines the ability of dispersion models such as AERMOD to provide detailed descriptions of concentration patterns and the ability of photochemical models such as CMAQ to capture the effects of atmospheric processes. Modeling using these improved methods is currently being done in Baltimore and Atlanta to support near road health studies. Finally, in cooperation with OAR, ORD is developing a line source algorithm for AERMOD, which will enable dispersion modelers to account for impacts of vehicle-induced turbulence along roadways.

Impacts and Outcomes: Research on near-road pollution has been used to support more stringent emission standards for heavy duty vehicles and engines, and was a key component of the public health case for the 2007 mobile source air toxics rule. Studies of near-roadway concentration gradients were critical in regulatory decisions requiring the U.S. Department of Transportation to ensure that new highway and transit projects in nonattainment areas will not cause or worsen nonattainment or delay timely attainment. In addition, near road research is being used in the integrated science assessments for NO_2, CO, PM, and lead. This research was also instrumental in developing communication materials on near-road impacts for EPA regional and state environmental agencies. Finally, work on roadway design has provided the transportation planning community with potential options to mitigate impacts of near-road pollution.

Future Directions: ORD's ongoing research on linkages between traffic activity/emissions, near-roadway pollutant gradients, the composition of the pollutant mixture near roads, and observed health effects in exposed populations will result in a better understanding of source to health effect relationships. This work will continue to be critical in setting future air quality standards, determining control strategies for motor vehicle emissions, developing models for regulatory applications and research assessments, and developing approaches to roadway design and planning that better account for air quality.

Relevant Publications

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